**Introduction**

Intersil Real Time Clock (RTC) products now include many products with a variety of functions. Common functions include a low power 32,768kHz oscillator and also the ability to keep time in SRAM registers after initial time and date is set.

The power for RTC devices includes a \( V_{DD} \) source, and can also include a backup source of either a battery or large storage capacitor (super capacitor). In many applications the RTC device is the only device in a system that has an alternative power source such as the backup battery, so there can be unique demands placed on the device compared to other semiconductor products.

In addition, the RTC device has a communications bus, usually \( \text{I}^2\text{C} \), that has pull-up resistors which can go to a different power source than the RTC. The interrupt or frequency output pull-up can be connected to yet another voltage.

Some RTC devices contain non-volatile EEPROM storage, both for device control registers and for general purpose storage. The EEPROM is a robust storage method that can survive temperature extremes, millions of write cycles and up to 10 years of endurance. Despite the robust design, there are power and ground voltage transients that, although they exceed data sheet limits, are present in systems and may upset EEPROM memory cells. In addition, some applications may have \( \text{I}^2\text{C} \) communication during power-down, another possible source of upset.

**RTC Device Power Connections**

The typical applications circuit for the RTC is shown in Figure 1. This seemingly simple circuit has no less than 4 possible power connections:

- \( V_{DD} \) power (\( V_{POWER} \))
- \( \text{I}^2\text{C} \) bus open drain pull-up power (\( V_{BUS} \))
- Battery backup (\( V_{BAT} \))
- Frequency output or interrupt open drain pull-up (\( V_{FOUT} \))

Having four different power sources raises the issue of power sequencing. Ideally, the RTC circuit will have 3 of the four power sources in common. The \( V_{CC} \), \( V_{BUS} \) and \( V_{FOUT} \) should all connect to the main \( V_{POWER} \) source, and when that is the case there are virtually no concerns with power sequencing.

Many applications prefer to have these connections powered separately. Examples include:

- RTC device is powered down while the \( \text{I}^2\text{C} \) bus and microcontroller are active (not recommended since it will violate RTC data sheet, but RTC devices are OK in this state).
- RTC device is powered down while the \( V_{FOUT} \) or \( \text{IRQ} \) is pulled up to \( V_{BAT} \) to allow a wake-up interrupt or clock while other circuits are asleep (this is OK, but the RTC data sheet absolute maximum ratings need to be followed).
- RTC device is powered from a higher or lower voltage than the \( \text{I}^2\text{C} \) pull-ups (this may or may not be allowed, possible unreliable operation).
- RTC device operates with one supply voltage and the \( V_{BAT} \) pin is grounded (this is OK, and is covered later in this document).

Table 1 provides some guidance when designing an RTC applications circuit.
Addressing Power Issues in Real Time
Clock Applications

Powering the RTC ON and OFF

Most Intersil RTC devices contain an internal power switch that applies the battery power to the internal circuitry when the VDD voltage drops below a certain threshold. That threshold is generally selectable, depending on the device (see applicable data sheet).

Since the RTC device is very low power, the switch circuitry is fairly slow, and can take more than 50µs to completely switch to the battery voltage. If the VDD power-down ramp is faster than this time, the internal RAM registers may not have sufficient voltage to retain their values and may become corrupted or reset altogether.

If a VDD power source needs to power-down quickly for some reason, the RTC should have some extra capacitance at the VDD pin to slow down the ramp to >50µs. If the extra capacitance is not realistic, then a small series resistor can be added to form an R-C network which will give the RTC a dedicated power-down and power-up waveform. Since the supply current for RTC’s can go up to 1mA or 2mA during write functions (if EEPROM is included), then it’s a good idea to use about a 100Ω resistor to keep the maximum drop reasonable.

Power Supply Turn-On Issues

Some applications involving the RTC device may unknowingly expose the device to excessive transients which may not permanently damage the device, but may corrupt the EEPROM and SRAM contents. Specifically, those applications which use offline AC power and switch it on and off can produce voltage bounces on the ground or VDD, or both, with enough energy and fast enough speed to propagate across a PC board despite bulk and decoupling capacitance at supply pins. In some cases, the energy supplied and the resulting current pulse is so large and fast that high intensity spikes can occur, capable of producing voltages exceeding the absolute maximum for IC’s. For negative pulses, the internal ESD diodes can absorb this energy but are limited, and the resulting negative excursion can be many volts, triggering latch-up or disruptive events. The RTC device can be uniquely susceptible to this bounce since it has a battery input and is expected to retain proper data in the SRAM through power turn-on and turn-off. In cases where the battery input is grounded, a device with EEPROM can have the data bits corrupted. It requires a large amount of energy to do this, with device currents and voltages that exceed the absolute maximum ratings.

---

### TABLE 1. RTC POWER CONNECTION GUIDELINES

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>VDD</th>
<th>SCL</th>
<th>SDA</th>
<th>FOUT/IRQ</th>
<th>VBAT</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Normal Operation, 5V</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>&lt;5.0V</td>
<td>All pull-ups same source as VDD. No Issues. OK if VBAT is a super capacitor.</td>
</tr>
<tr>
<td>2 Normal Operation, 3.3V</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.3V</td>
<td>&lt;3.6V</td>
<td>OK. Normally VBAT up to 5.5V (super capacitor) is OK. Check applicable data sheet.</td>
</tr>
<tr>
<td>3 Split Supplies, Low Voltage Four/IRQ-</td>
<td>5V</td>
<td>5V</td>
<td>5V</td>
<td>3.3V</td>
<td>&lt;5.0V</td>
<td>OK. The FOUT can connect to 3.3V circuits reliably.</td>
</tr>
<tr>
<td>4 Split Supplies, Lower Voltage I2C (a)</td>
<td>5V</td>
<td>3.3V</td>
<td>3.3V</td>
<td>5V or 3.3V</td>
<td>&lt;5.0V</td>
<td><strong>Will not work.</strong> The VINT for the I2C is based on VDD and prevents communications.</td>
</tr>
<tr>
<td>5 Split Supplies, Lower Voltage I2C (b)</td>
<td>5V</td>
<td>VBAT</td>
<td>VBAT</td>
<td>5V or 3.3V</td>
<td>&lt;3.5V</td>
<td><strong>Will not work.</strong> The VINT for the I2C is based on VDD and prevents communications, especially as VBAT discharges. VBAT discharges too quickly.</td>
</tr>
<tr>
<td>6 Split Supplies, High Voltage VBAT, Variable Voltage I2C</td>
<td>3.3V</td>
<td>VBAT</td>
<td>VBAT</td>
<td>3.3V</td>
<td>&lt;5.0V</td>
<td>Will work on <strong>SOME</strong> RTC’s. Be careful for VBAT &gt; VDD as the device may not access I2C in this mode or can draw high VBAT current. Check applicable data sheet. Note that with VBAT discharging to 2.0V or below, the VINT will be too low for VDD-referenced I2C. VBAT discharges too quickly.</td>
</tr>
<tr>
<td>7 Split Supplies, Low voltage VBAT, Variable Voltage I2C</td>
<td>3.3V</td>
<td>VBAT</td>
<td>VBAT</td>
<td>3.3V</td>
<td>&lt;VDD</td>
<td>Will work on <strong>MOST</strong> RTC’s. Check applicable data sheet. Note that with VBAT discharging to 2.0V or below, the VINT will be too low for VDD-referenced I2C. VBAT discharges too quickly.</td>
</tr>
<tr>
<td>8 Split Supplies, Higher Voltage I2C</td>
<td>3.3V</td>
<td>5.0V</td>
<td>5.0V</td>
<td>3.3V</td>
<td>&lt;5.0V</td>
<td>Will work on all RTC devices but <strong>NOT ADVISED.</strong> Potential for latch-up and high VBAT current exists, some RTC may have issues. Follow absolute maximum ratings on data sheet.</td>
</tr>
<tr>
<td>9 Split Supplies FOUT has One Supply and VDD another, Low Voltage VDD</td>
<td>3.3V</td>
<td>3.3V</td>
<td>3.3V</td>
<td>5V or 3.3V</td>
<td>3.0V to 5.0V</td>
<td>Will work on all RTC devices but not advised. If unavoidable, make sure to apply both supplies at close to the same time.</td>
</tr>
</tbody>
</table>

**NOTE:** Consult data sheet for RTC VDD operation below 2.7V.
The worst case scenario is where the AC waveform is near its peak during turn-on and the board instantly sees that peak before passive devices absorb the energy.

Normal power supply filtering does help prevent this, and adding small amounts of inductance can improve it or make it worse, depending on the location of the inductance and decoupling capacitance. The best prevention is to add a medium power Schottky diode at the RTC, anode at ground and cathode at \( V_{DD} \), which can clamp the voltage across the device to a safe value at higher currents than the internal ESD structures. A good low leakage diode such as the BAT54 is recommended.

**Power Glitches or Interruptions**

The battery backup design for RTC’s is there to insure the device retains the time/date in the event the power is turned off or interrupted for some reason. Battery backup works fine for most applications where the power is turned off and on predictably. Occasions arise where there may be fast glitches or excursions of the \( V_{DD} \) beyond the absolute maximum limits, and these will cause problems. If a fast glitch is generated by power switching or interruption, then RAM contents can be corrupted or reset (see section “Powering the RTC ON and OFF” on page 2). Again, local filtering of the \( V_{DD} \) may be needed to prevent memory corruption.

Many Intersil RTC devices contain a power-up delay function to prevent accidental access by the serial bus before power is stable and devices on a board are functioning properly. This delay is normally about 90ms, and some older devices may have a 3 second delay. After the glitch or power-up, the delay is triggered and the device will not respond to an I2C communication until the timeout period is over. If a customer is unsure about this function in their application, they should contact Intersil.

**Powering the RTC with NO or VERY LOW \( V_{BAT} \)**

RTC device operation relies on stable contents in the internal registers. These SRAM registers get loaded with values either from EEPROM or default hard-coded values on power-up, depending on the RTC device type. There are two circuit configurations which lend themselves to corruption of the SRAM registers:

1. **The \( V_{BAT} \) pin is grounded**

   In this case there is just a main \( V_{DD} \) power source which may power-down occasionally. If this voltage is allowed to float to a non-zero state on power-down, the ensuing power-up may put the SRAM registers in an unknown state.

   Practical tests have shown that the SRAM registers can maintain their contents down to \( V_{DD} = 1.0V \) at room temperature. Once \( V_{DD} \) drops to <0.2V and then rises to its normal level, then the default values will be loaded. With \( V_{DD} \) stalled in the range from 0.2V to 1.0V (the “High Risk” range) on power-down, the SRAM registers can be in an unknown value on power-up.

   Note that the \( V_{DD} \) power glitch to this lower voltage for a period of time can also trigger the SRAM corruption. If the glitch is not recognized by the rest of the system the RTC device can lose SRAM bits without notice. Practical tests show that the glitch would need to be minimum 50µs to 100µs duration to cause a problem.

   A solution for corrupted RTC SRAM on power-up is to add a series resistor and clamp MOSFET to the RTC \( V_{DD} \) as shown in Figure 2.

   Applying a logic high to the RTC_SD node (\( M_1 \) gate) will cause \( M_1 \) to saturate and discharge \( C_1 \) while pulling current through \( R_S \). This action clamps the \( V_{RTC} \) node (\( V_{DD} \) low, to around 20mV-30mV or less. When the logic signal is released, \( C_1 \) will charge up through \( R_S \) and \( V_{DD} \) will be powered up normally, with registers in the correct default or EEPROM recalled states. \( R_S \) must be chosen so that there enough headroom for the RTC to operate at maximum \( V_{DD} \) current, which is normally for an I2C write. RTC devices containing EEPROM will draw more current, about 1mA during write operations and will need a smaller \( R_S \) value.

---

**FIGURE 2. POWERING A DEVICE WITH NO BATTERY BACKUP**
A secondary benefit of the $R_C-C_1$ circuit is filtering glitches, preventing unwanted noise on the $V_{DD}$ pin. Note that the SDA, SCL and IRQ/FOUT pins all are powered through pull-ups during the $V_{DD}$ power cycle. This state is allowed short term and will not harm the device.

2. $V_{BAT}$ is allowed to drop into the high risk range

In this case, the backup supply may discharge to a very low voltage ($0.2V < V_{BAT} < 1V$ is considered very unreliable for backup power, as well). Now the RTC device is relying on $V_{BAT}$ bias to power the SRAM registers and maintain their contents. When the $V_{BAT}$ level drops to a low voltage, but not zero, it may be too low to maintain the SRAM bits and once $V_{DD}$ power is cycled, they will either corrupt the current contents or incorrectly recall the default or EEPROM settings. Unless the system monitors the battery voltage, it will assume all RTC functions are normal.

If the system can detect bad data from the RTC or low $V_{BAT}$ has been detected, then the battery should be replaced and the device should restore original SRAM register settings before operation proceeds.

The circuit from Figure 3 can be used with the jumper $J_{BAT}$ for manually disconnecting the battery to allow the device to reset if the battery or super capacitor is discharged. Once the battery is changed or the super capacitor is charged again, the jumper can be replaced.

I$^2$C Communication During Power-Down

Most systems will have an orderly power-down sequence, including completing I$^2$C communications before complete power voltage shutdown. If that is not possible, then I$^2$C communication during battery switchover can occur which may result in erroneous register writes. These register writes could result in incorrect data being written to a valid address, or having correct data written to an incorrect address. Either way, the erroneous write could change data in EEPROM (if it exists) or battery backed SRAM. Erroneous data in RTC control registers can result in the device not operating properly, even preventing I$^2$C communication with $V_{DD}$ powered up.

Steps should be taken to prevent any I$^2$C activity during $V_{DD}$ power-down situations.

Conclusions

Intersil RTC devices are designed to provide a reliable clock and calendar function with battery backed up data in registers. There are some power supply situations that need to be considered in order to maintain reliable data and also serial bus communication. With these considerations, RTC applications can be made reliable and robust.

FIGURE 3. SUGGESTED BATTERY-BACKUP CIRCUIT
Notice

1. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation or any other use of the circuits, software, and information in the design of your product or system. Renesas Electronics disclaims any and all liability for any losses and damages incurred by you or third parties arising from the use of these circuits, software, or information.

2. Renesas Electronics hereby expressly disclaims any warranties against and liability for infringement or any other claims involving patents, copyrights, or other intellectual property rights of third parties, by or arising from the use of Renesas Electronics products or technical information described in this document, including but not limited to, the product data, drawings, charts, programs, algorithms, and application examples.

3. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.

4. You shall not alter, modify, copy, or reverse engineer any Renesas Electronics product, whether in whole or in part. Renesas Electronics disclaims any and all liability for any losses or damages incurred by you or third parties arising from such alteration, modification, copying or reverse engineering.

5. Renesas Electronics products are classified according to the following two quality grades: “Standard” and “High Quality.” The intended applications for each Renesas Electronics product depends on the product’s quality grade, as indicated below.

- “Standard”: Computers, office equipment, communications equipment, test and measurement equipment, audio and visual equipment, home electronic appliances, machine tools, personal electronic equipment, industrial robots, etc.

- “High Quality”: Transportation equipment (automobiles, trains, ships, etc.), traffic control (traffic lights), large-scale communication equipment, key financial terminal systems, safety control equipment, etc.

Unless expressly designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not intended or authorized for use in products or systems that may pose a direct threat to human life or bodily injury (artificial life support devices or systems; surgical implants, etc.), or may cause serious property damage (space system; underwater repeaters; nuclear power control systems; aircraft control systems; key plant systems; military equipment; etc.). Renesas Electronics disclaims any and all liability for any damages or losses incurred by you or any third parties arising from the use of any Renesas Electronics product that is inconsistent with any Renesas Electronics data sheet, user’s manual, or other Renesas Electronics document.

6. When using Renesas Electronics products, refer to the latest product information (data sheets, user’s manuals, application notes, “General Notes for Handling and Using Semiconductor Devices”) in the reliability handbook, etc., and ensure that usage conditions are within the ranges specified by Renesas Electronics with respect to maximum ratings, operating power supply voltage range, heat dissipation characteristics, installation, etc. Renesas Electronics disclaims any and all liability for any malfunctions, failure or accident arising out of the use of Renesas Electronics products outside of such specified ranges.

7. Although Renesas Electronics endeavors to improve the quality and reliability of Renesas Electronics products, semiconductor products have specific characteristics, such as the occurrence of failure at a certain rate under malfunctions under certain usage conditions. Unless designated as a high reliability product or a product for harsh environments in a Renesas Electronics data sheet or other Renesas Electronics document, Renesas Electronics products are not subject to radiation resistance design. You are responsible for implementing safety measures to guard against the possibility of bodily injury, injury or damage caused by fire, and/or danger to the public. In the event of a failure or malfunction of Renesas Electronics products, such as safety design for hardware and software, including but not limited to, redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult and impractical, you are responsible for evaluating the safety of the final products or systems manufactured by you.

8. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. You are responsible for carefully and sufficiently investigating applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive, and using Renesas Electronics products in compliance with all these applicable laws and regulations. Renesas Electronics disclaims any and all liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

9. Renesas Electronics products and technologies shall not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations. You shall comply with any applicable export control laws and regulations promulgated and administered by the governments of any countries asserting jurisdiction over the parties or transactions.

10. It is the responsibility of the buyer or distributor of Renesas Electronics products, or any other party who distributes, disposes of, or otherwise sells or transfers the product to a third party, to notify such third party in advance of the contents and conditions set forth in this document.

11. This document shall not be reprinted, reproduced or duplicated in any form, in whole or in part, without prior written consent of Renesas Electronics.

12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its directly or indirectly controlled subsidiaries.

(Note 2) “Renesas Electronics products” means any product developed or manufactured by or for Renesas Electronics.